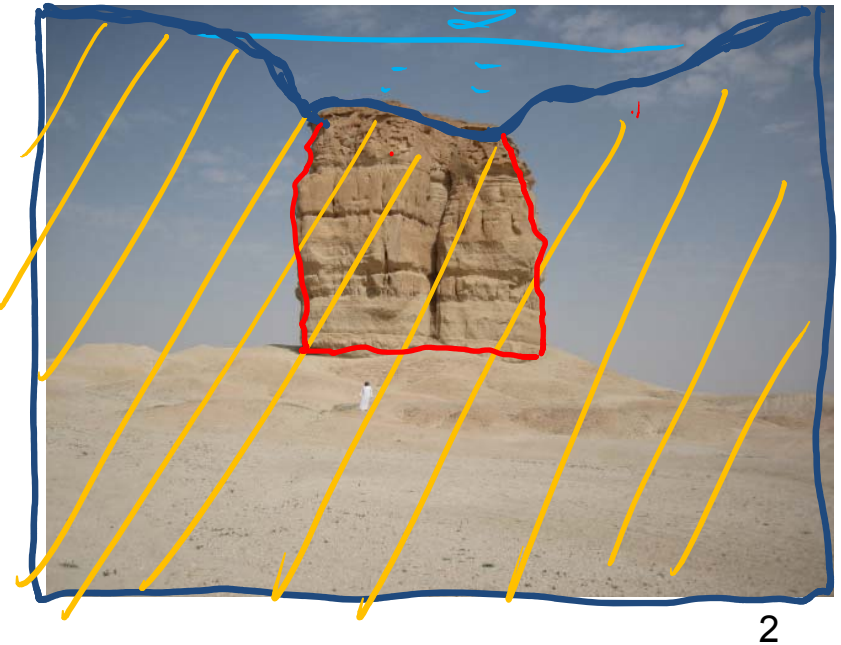
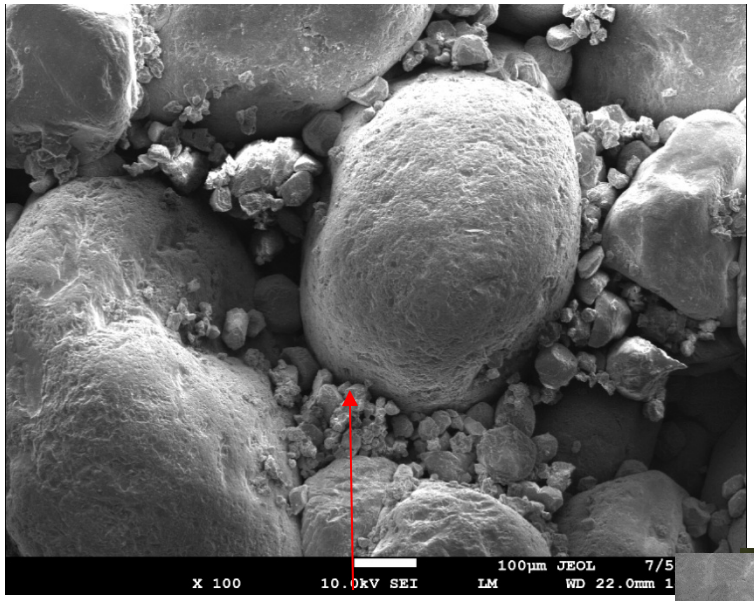
Biocementation Method for Soil Improvement

What is biocement

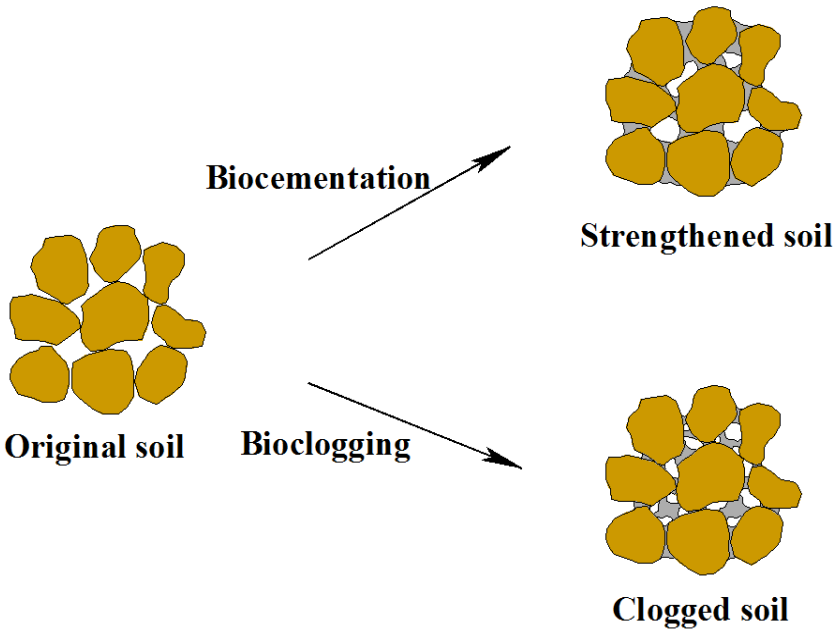
- ***Biocement –*** A construction material made of naturally occurring microorganisms and other materials at ambient temperature.



Mechanisms



Scanning Electron Micrograph (SEM) showing the formation of Crystals of $CaCO_3$



Bonding of sand grains by slime

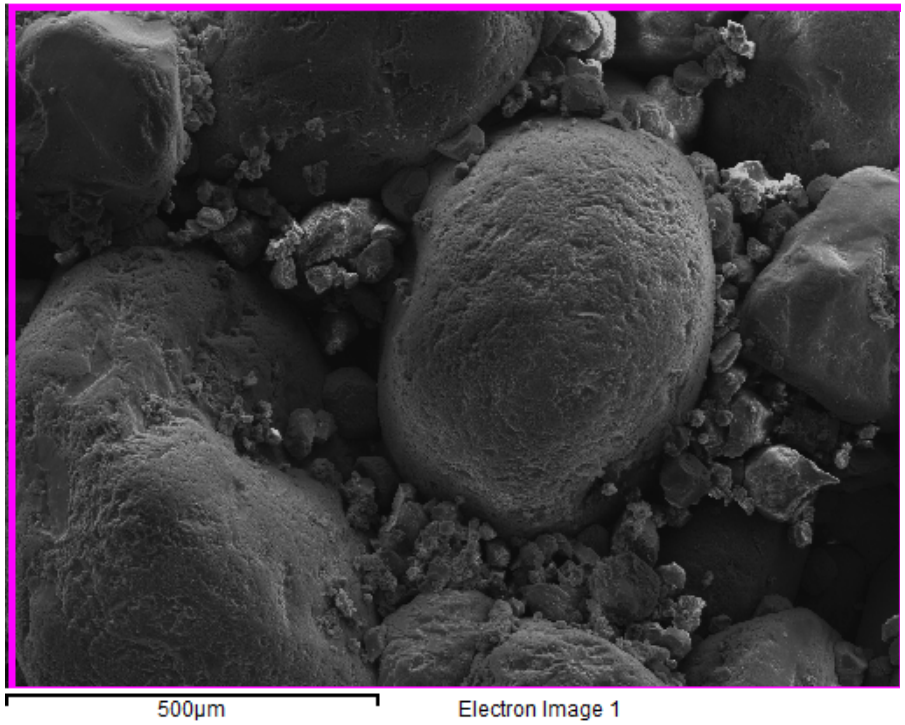
Production of $CaCO_3$ or $Fe(OH)_3$

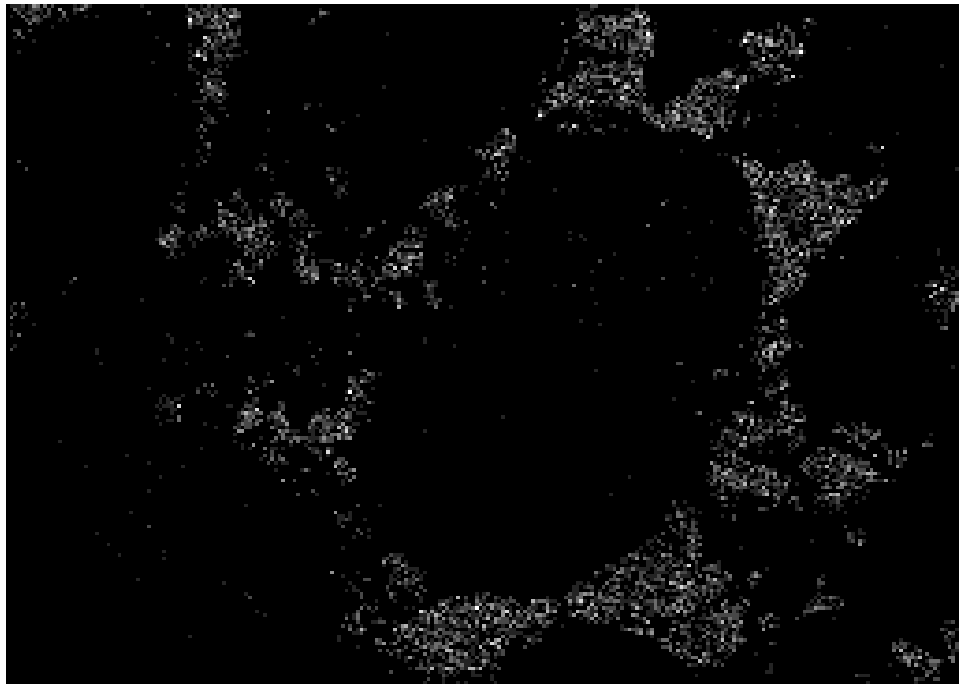
- This process is often called “microbially induced calcium carbonate precipitation” (MICP).
- Urease-producing bacteria (UPB) accelerate decay of urea to ammonium and carbonate in solution containing urea and calcium chloride :

  $(NH_2)_2CO + 3H_2O \rightarrow 2NH_4^+ + HCO_3^- + OH^-$
- Due to this reaction, pH is increased and hydrocarbonate is produced. Crystallization of calcite is formed bind soil particles:

  $CaCl_2 + HCO_3^- + OH^- \rightarrow \mathbf{CaCO_3}\downarrow + H_2O + 2Cl^-$
- Or to use Iron-based biogrout (iron carbonate or Iron (III) Hydroxide)
- $2NH_4^+ + 2OH^- + FeSO_4.7H_2O + CO_2 \rightarrow FeCO_3 + 8H_2O + (NH_4)_2SO_4$
- $Fe + 3OH^- \rightarrow \mathbf{Fe(OH)_3}$

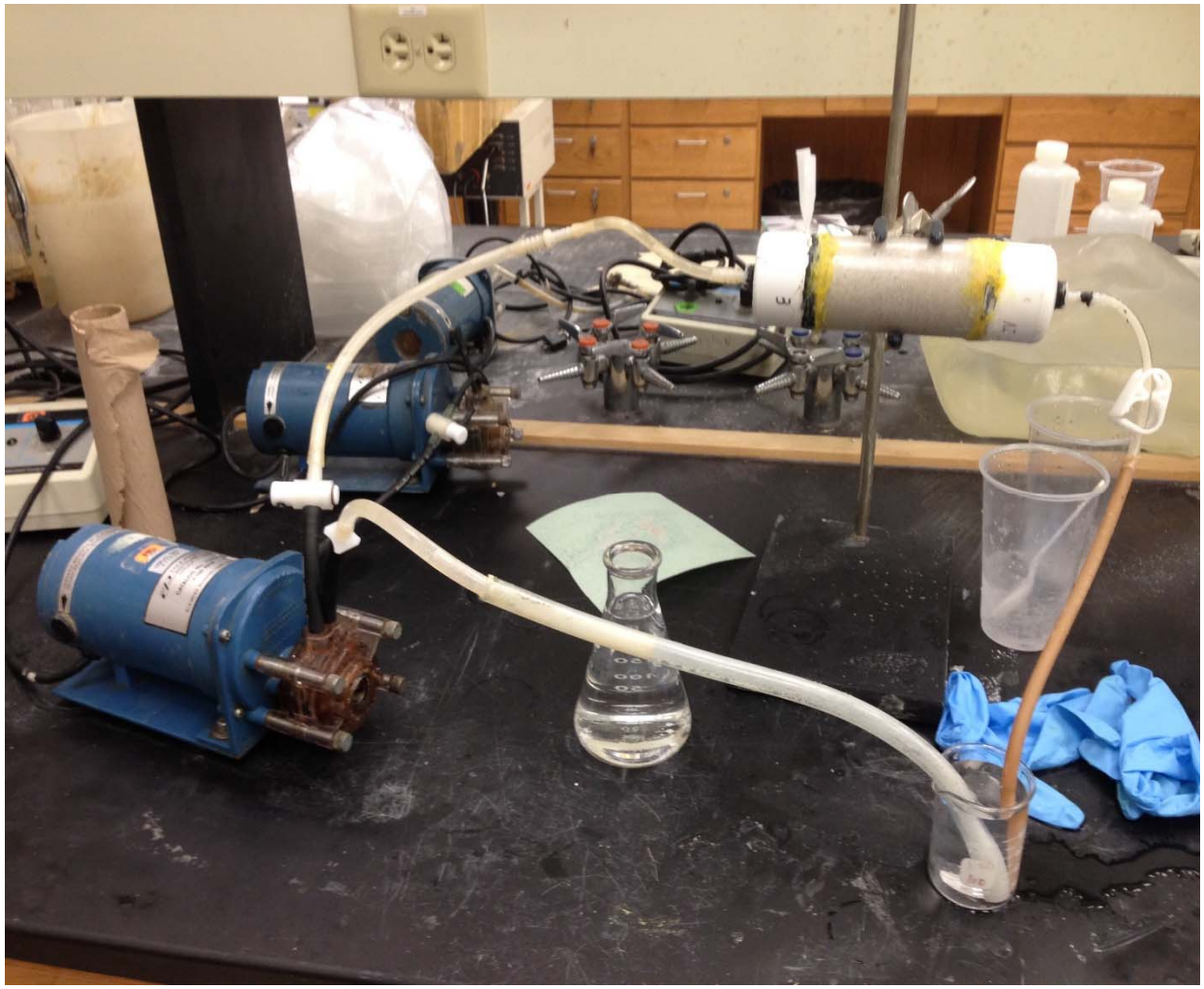
FESEM & EDX for biocemented sand





Ca Ka1

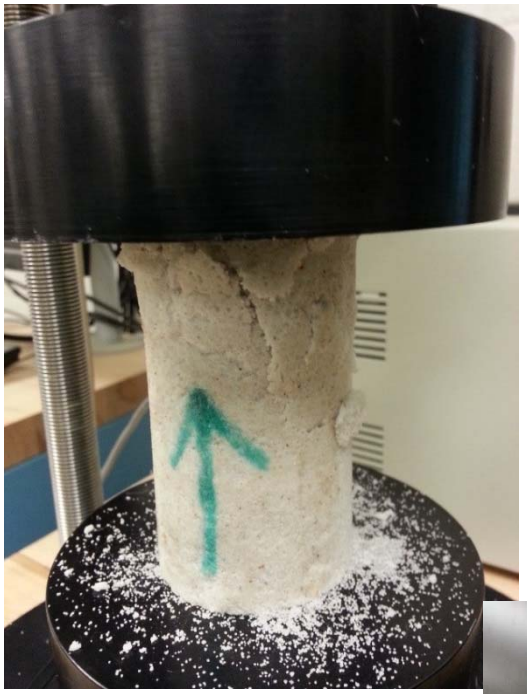
In-situ Test

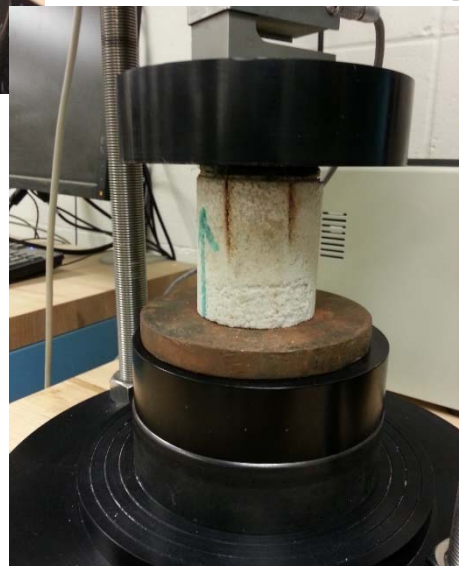


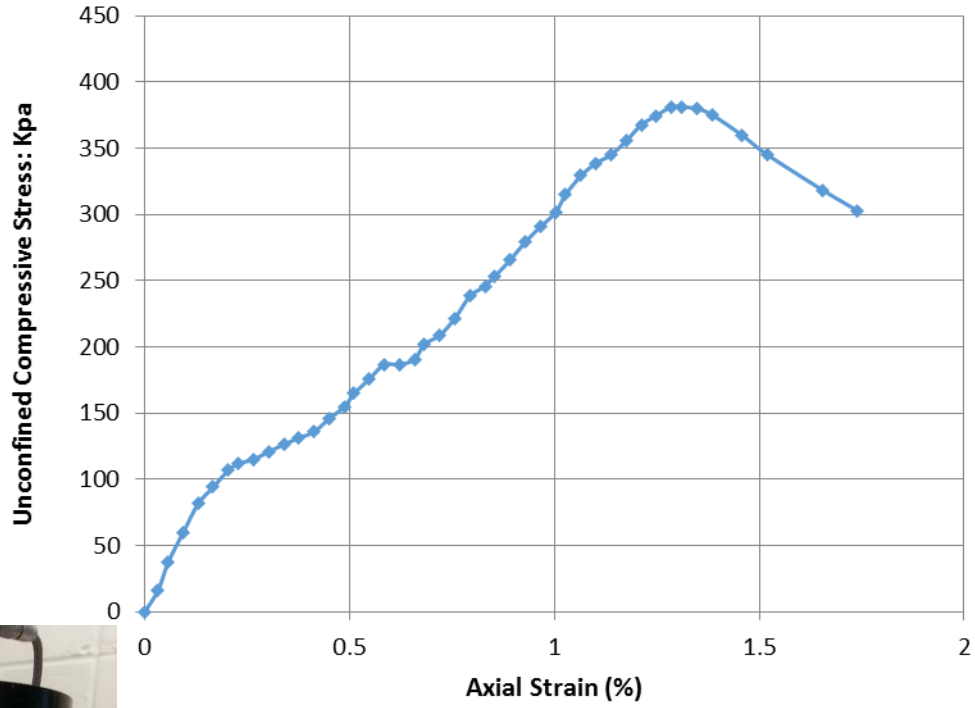
Sand Column treated by biocement

By treating sand using biocement for 2 weeks and 14 treatments, the sand turns into a hard column.

Shear Strength Test





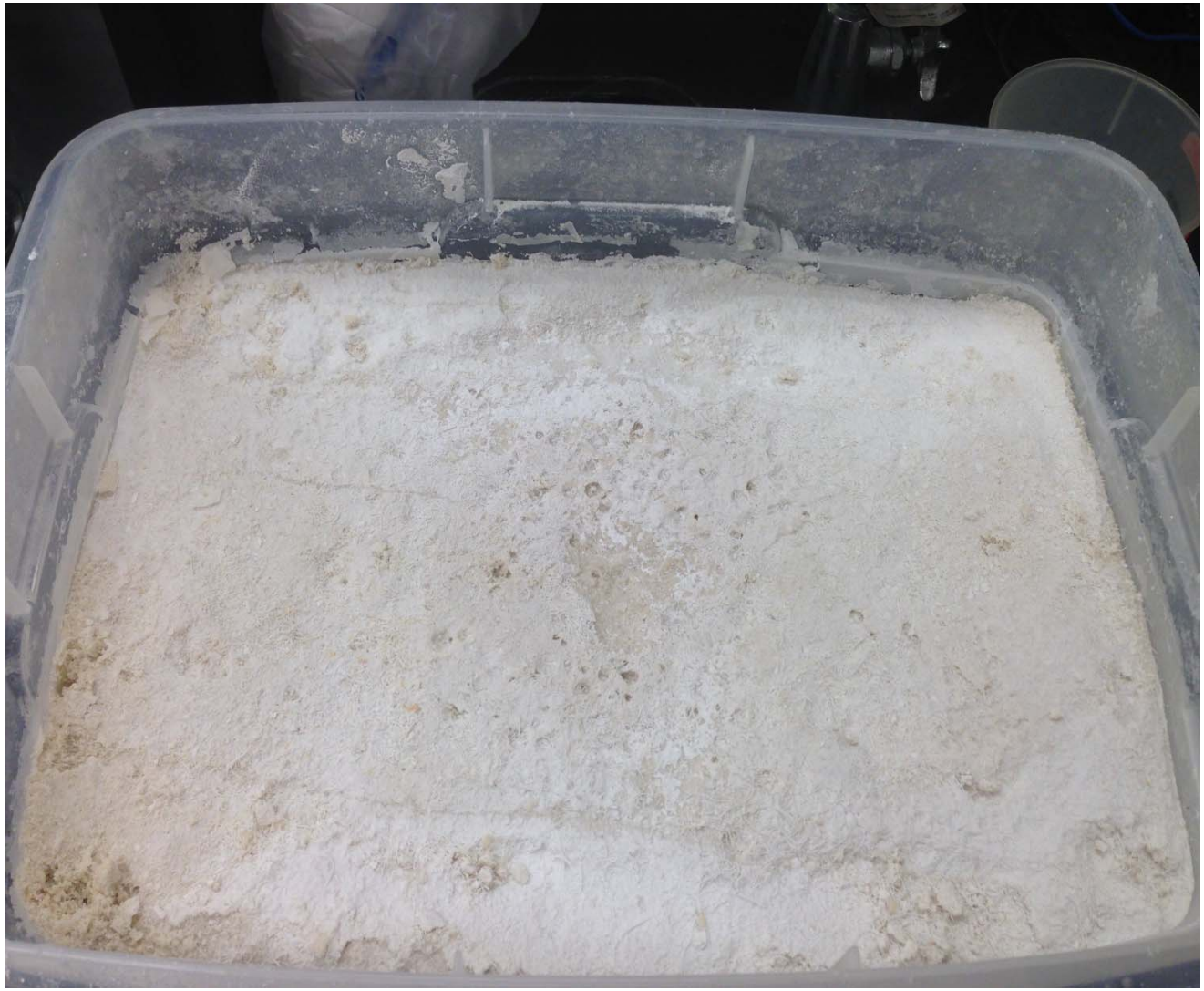


Calcium Content Test

	Before the Test	After the test	Differential Value	[Ca^{2+}] %
Weight (g)	3.1738	2.5562	0.6176	9.6643
Weight (g)	3.2880	2.8506	0.4374	6.1377
Weight (g)	3.4763	3.0064	0.4699	6.2520
Average	3.3127	2.8044	0.5083	7.2500

For the unconfined consolidation test, the results show the unconfined compressive strengths of the sand treated with calcium-base after 14 treatments, these samples have formed a relatively strong compressive strength and high calcium ion content.

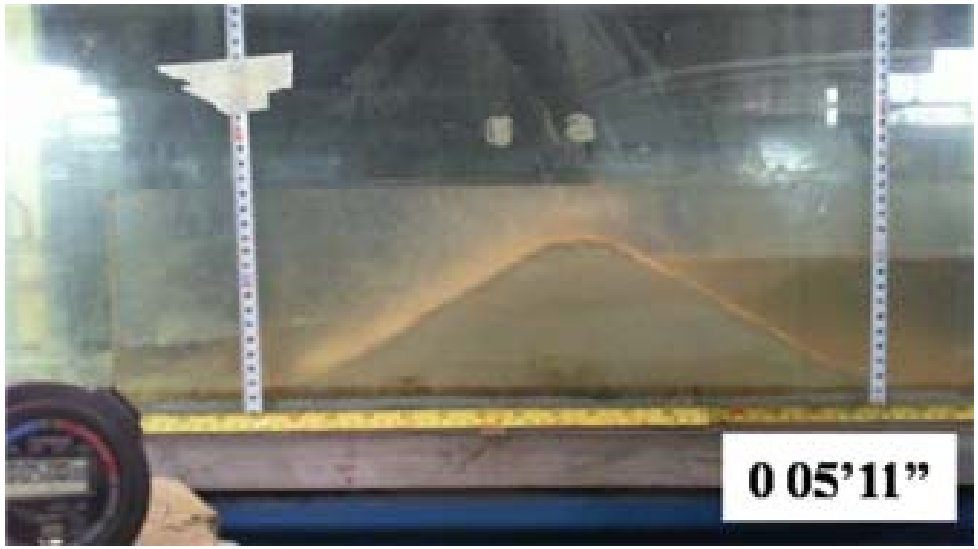
Big Box Test by Biocement



After the bio-cement training process, the top surface of the sample is very hard, like the surface of rock.

Other Applications: Model Test

Model levees were built using Ottawa sand (d_{50} = 0.4 mm).
Bacteria liquid with $CaCl_2$ and urea solution was sprayed on the surface of the models using a spray bottle for 6 times.



a

c

j

Model levee was put in a hydraulic flume for testing under overtopping flow.

Other Applications: For base or subbase

UC Strength of 6 MPa can be achieved in the lab

Mix biogrout with aggregates and limestone fines to form a biomortar

Biomortar can be used for base or subbase

In Conclusion

Biocementation improves soft soil by increasing the shear strength of soil, also reduce the water conductivity of soil or the rate of water flow in the soil.